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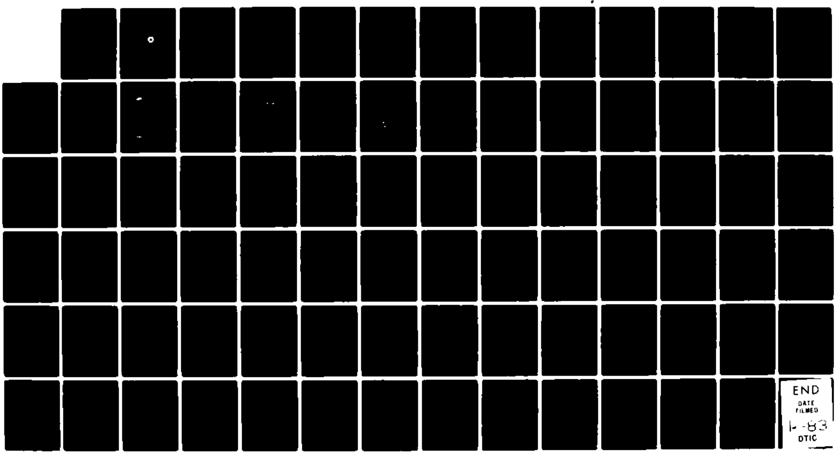

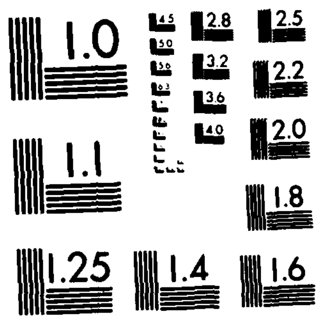
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UNIT PRODUCTION COST OF THE RADAR BEACON TRANSPONDER (RBX)

FINAL REPORT

A. Schust
W. Lovelace
K. Peter

October 1982

PREPARED FOR

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
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16. Abstract

This report presents the results of a unit production cost analysis of the Radar Beacon Transponder (RBX).

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METRIC CONVERSION FACTORS

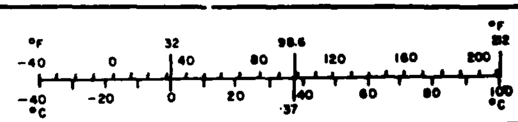
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



ACKNOWLEDGMENT

Throughout this study, ARINC Research Corporation received enthusiastic and invaluable support from the engineering and management staffs of the Federal Aviation Administration (FAA). Special acknowledgment is made to T. Morgan of the FAA.

SUMMARY

This report presents the results of a study conducted by ARINC Research Corporation to develop the unit production cost of the Radar Beacon Transponder (RBX). The study was conducted for the Federal Aviation Administration (FAA) Systems Research and Development Service (SRDS) and Office of Systems Engineering Management (OSEM) under Contract DOT-FA76WA-3788.

On the basis of circuit and equipment designs developed by ARINC Research, the unit production cost (factory selling price) of the RBX was determined to be $53,190. Equipment costs were derived using the accounting method of cost estimating. System development and production tooling costs were not included in the unit production cost. All costs are based on 1981 dollars without inflation. Table S-1 summarizes the cost analysis of the RBX.

Table S-1. RBX TRANSPONDER COST (1981 DOLLARS)

Equipment	Cost
Receiver-Processor	7,813
Transmitter	29,640
Performance Monitor	8,877
Power Supplies	1,734
Cabinet	3,684
Antenna	1,442
Factory Selling Price	53,190

ARINC Research Corporation developed a modular transmitter design that used four 1,150-watt amplifier modules. Using the appropriate number of amplifier modules, we were able to estimate the costs of a 1 kilowatt (1 kW) transmitter and a 2 kW transmitter -- $9,580 and $17,530, respectively. On the basis of these costs, the cost of an RBX with a 1 kW

transmitter would be approximately $33,130; an RBX with a 2 kW transmitter would cost approximately $41,080. It is emphasized, however, that if we were designing an RBX with a 1 kW or 2 kW transmitter, the transmitter design might be completely different.

CONTENTS

CONTENTS (continued)

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The Federal Aviation Administration (FAA) is developing the Radar Beacon Transponder (RBX) to provide automatic control of Beacon Collision Avoidance System (BCAS) activity within specified distances from terminal areas. The technical staff at FAA Technical Center assembled and tested an engineering model of the RBX, using existing hardware modified for RBX operation. However, this engineering model did not reflect the expected production designs that would be generated by competitive procurement.

The FAA Systems Research and Development Service (SRDS), in conjunction with the Office of Systems Engineering Management (OSEM), tasked ARINC Research Corporation, under Contract DOT-FA76WA-3788, to develop the unit production cost of RBX equipment in quantities of 100 to 200 systems.

1.2 PROJECT OVERVIEW

The objective of this analysis was to develop an independent assessment of the unit production cost of electronics required to implement the RBX. ARINC Research Corporation developed the unit production cost of the RBX system, using the cost accounting method of cost estimating. This report presents the results of the evaluation. The results are presented in 1981 dollars, consistent with the technology and available data on which the estimates were based.

1.3 ORGANIZATION OF THE REPORT

The six chapters of this report address the RBX design and the technique used for estimating the unit production cost, and present the results of the analysis.

Chapter Two describes the cost estimating methodology used to obtain the desired unit production costs. Chapter Three presents the RBX configuration. Chapter Four presents the cost development for the RBX, and

Chapter Five presents cost developments for variations of the RBX transmitter design. Chapter Six summarizes the results of the analysis. Finally, Appendixes A through D are detailed cost sheets associated with the analysis, and Appendix E presents the microprocessor system interface diagram.

CHAPTER TWO

COST ESTIMATING METHODOLOGY

ARINC Research developed the cost of the RBX by converting engineering requirements and functional specifications to a possible production equipment design. The ARINC Research design allowed for development of a detailed bill of materials.

2.1 RETAIL COST METHOD

The technique chosen for the cost evaluation is the industry standard accounting method of estimating production costs on the basis of estimates of the numbers and types of piece parts. The method requires detailed bills of materials and associated labor units, schematic diagrams, mechanical and electronic module layouts, and total quantity of units to be manufactured. Material costs are based on original equipment manufacturer (OEM) price lists in component quantities of 1,000 or greater. Allowances are made for large parts procurements common to equipment manufacturers. Finally, the accounting structures of potential manufacturers must be known to allow for labor, overhead charges, quality control costs, general and administrative (G&A) expenses, and the normal profits experienced in the electronics industry.

2.2 COST INPUT DATA

The data necessary for preparing cost estimating work sheets using the accounting method are usually taken directly from engineering bills of materials. The component part numbers are identified, and quantities are entered on the work sheets. Procurement costs of the components are obtained either from OEM price lists or, in cases where the component is unique or in a high-cost category, through direct quotes provided by OEM distributors. Labor associated with fabrication or assembly of components is estimated in terms of hours per 1,000 units in a mass production assembly line. Most manufacturers maintain historical data containing the average labor estimates for both manual and automatic insertion processes. These data provide the average labor hours associated with assembly of the components configured in a module (e.g., printed circuit card) or a subassembly. The total labor hours are comparatively evaluated to determine the complexity of the assembly in relation to the historical data.

If the module is complex (that is, it has high component density or requires printed circuit boards with multiple layers), a compensating complexity factor is applied to the labor estimate. A complexity factor is also applied to the labor estimate when the quantity production rates are small. The resulting material costs and labor estimates provide the data necessary for developing the cost estimating output sheets.

2.3 COST OUTPUT DATA

The work sheets used in developing total equipment costs are structured to provide cost information on individual modules (or subassemblies) and total equipment units. This method provides information that is useful in evaluating life-cycle costs in cases where module stockage and associated costs are necessary for determining the recurring and nonrecurring logistics costs. Total equipment unit costs include unit assembly, test, and integration costs incurred when the equipment package is completed.

Costs are developed by considering the expense of materials, material handling charges, labor at either known or estimated hourly rates, average overhead obtained from a sampling of manufacturers, and factory inspection costs during production. An allowance of 25 percent of these direct costs is made to cover production engineering and quality control, and the result is the factory cost of the subassembly or electronic unit. The addition of G&A costs, together with a reasonable profit, provides the OEM, or selling, price of the unit.

The output data sheets are also structured to permit easy reevaluation of the expected costs of electronics by substituting different labor, overhead, G&A, profit, and markup rates if there is sufficient concern over the data used or if a manufacturer prefers to use the exact factory rates rather than the indstry average.

CHAPTER THREE

RADAR BEACON TRANSPONDER CONFIGURATION

The purpose of the ground-based RBX is to control the threat-detection sensitivity level of the BCAS in appropriately equipped aircraft. The RBX will be used in Air Traffic Control (ATC) terminal areas where the Discrete Address Beacon System (DABS) is not installed. The RBX will also relay displayed BCAS resolution advisory data to an automated ATC terminal facility. This chapter describes the RBX design, which we developed from RBX engineering requirement FAA-ER-250-3 of 13 February 1981.

3.1 RBX TRANSPONDER DESIGN

To develop the bill of materials required in determining the unit production cost of the RBX, ARINC Research designed an RBX to meet the FAA's maintenance concept of the 1980s. Our design consists of five major modules housed in a 68-inch-high cabinet. All modules except the power supplies use packaging concepts that allow subassemblies of the modules to be plug-in field or line-replaceable units (LRUs). This allows the RBX to be restored to service with subassembly replacement in the event of a failure.

The five major modules that are integrated into the cabinet-mounted racks or drawers are the receiver-processor, transmitter, performance monitor, and two power supply modules. An omnidirectional antenna is also required. Figure 3-1 shows a possible RBX configuration.

Figure 3-2 presents a functional description of the entire RBX and displays the interconnection of the various modules in the system. The intent of the figure is to show the interrelationships of the major modules of the RBX.

3.2 RBX MODULES

3.2.1 Receiver-Processor

The receiver-processor module is packaged into a standard 19-inch drawer. It consists of an RF front end, two analog processing printed circuit boards (PCBs), two timing PCBS, and three digital PCBs containing

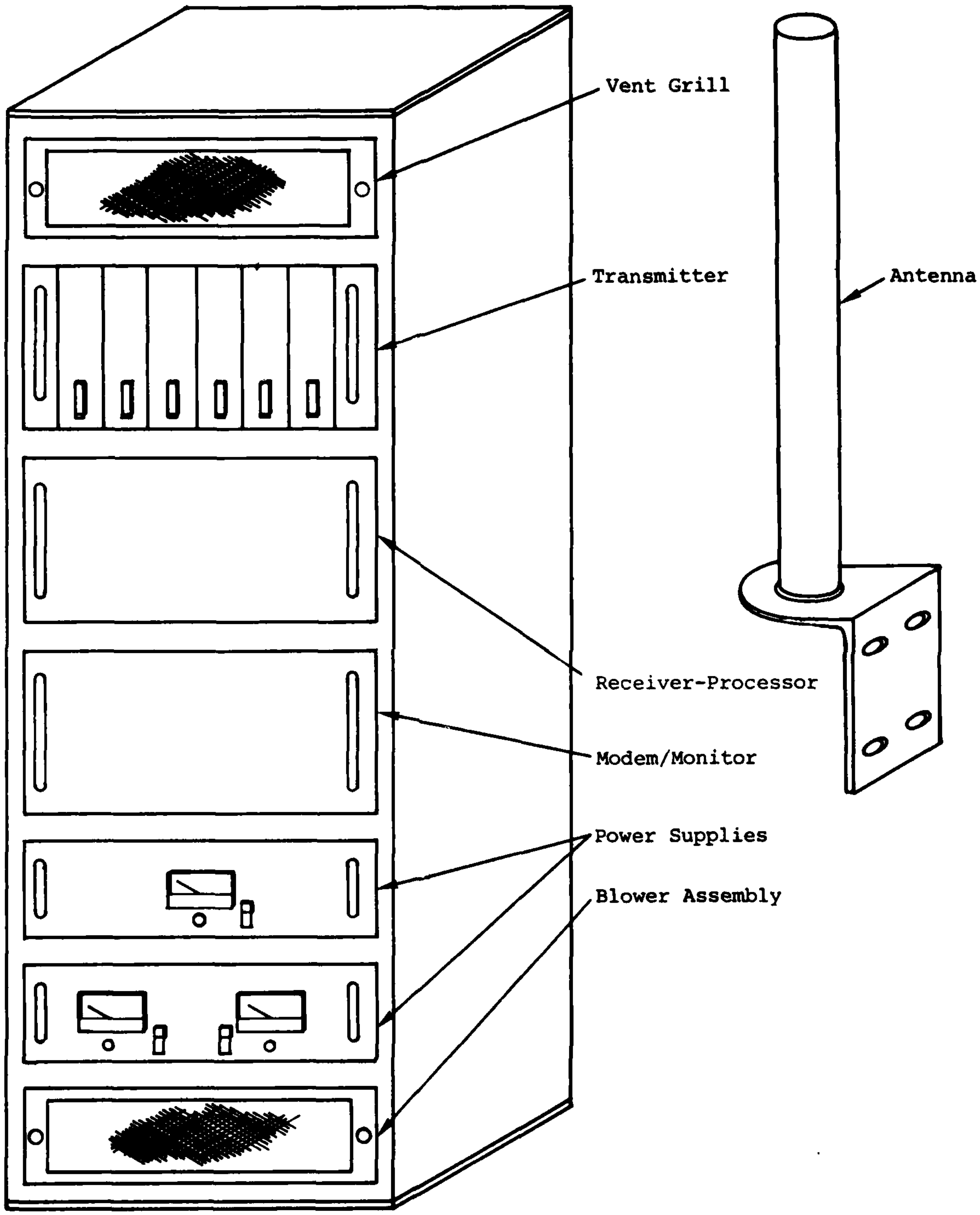


Figure 3-1. RBX AND ANTENNA ASSEMBLY

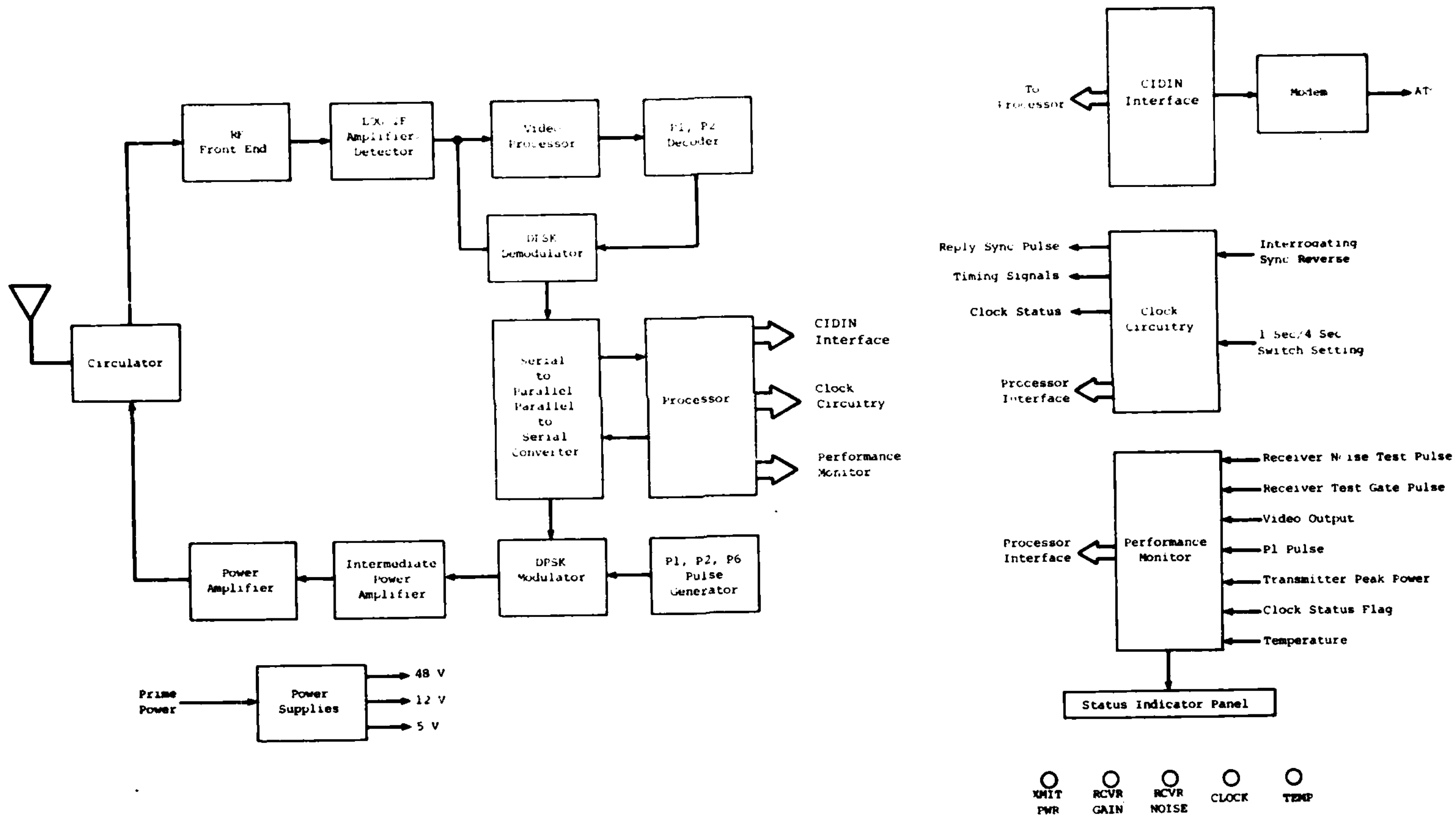


Figure 3-2. RBX Functional Diagram

a microprocessor, its peripherals, and associated controls. Inputs to and outputs from the receiver are through rear-mounted connectors. Figure 3-3 illustrates our concept of the receiver-processor module.

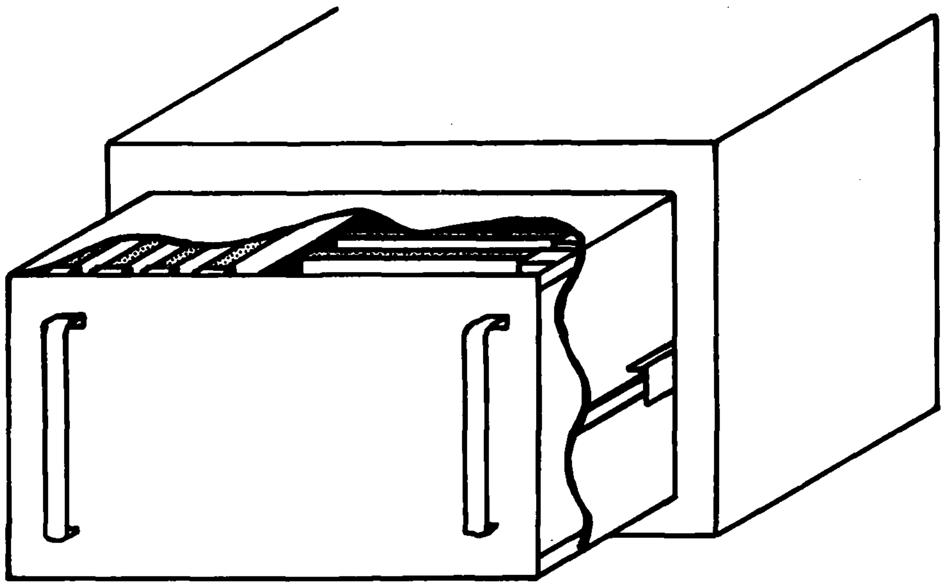


Figure 3-3. RBX RECEIVER-PROCESSOR MODULE

The RF front end consists of a coupler, preselector, and RF shielded casting. The casting, designed as an LRU, contains the limiter, low-noise amplifier (LNA), local oscillator, and mixer. The limiter, LNA, and local oscillator employ microstrip design techniques. The coupler, preselector, and mixer were considered to be purchased items. The casting enclosure was costed as a manufactured item. A high assembly time is associated with the RF front end, because matched rigid cable is used for interconnections.

The seven PCBs of the receiver-processor are standard 6-inch-by-8-inch PCBs. Four of the PCBs are contained in an RF shielded enclosure. Of these four, two contain the IF, pulse detection, pulse decoding, DPSK demodulation, and associated circuitry; one contains the timing clock circuitry; and the fourth contains the time-of-day PCB, which is a purchased item. The remaining three PCBs contain the processor circuitry.

The processor is a microprocessor-based data bus system whose primary function is data handling and sequencing. Appendix E shows the system interface schematic for the processor.

The sensitivity map for range and altitude is stored in a PROM to allow for possible changes. The sensitivity required by any interrogator is determined in an iterative manner. Once the 112-bit message from the BCAS is received and loaded into the data shift register, the microprocessor starts a sequence of events to determine the required sensitivity. The lowest altitude of the sensitivity map is presented to one side of a comparator, while the other side of the comparator looks at the transmitted altitude. The comparator sends a high, low, or equal response to the microprocessor. This cycle continues up the stored altitude map until a greater-than response is received on the interrupt line to the microprocessor. Each time a new altitude is recalled from the PROM, a counter is advanced. Whenever a cycle is run from the range map, a similar counter is advanced. The counter values are read into the PROM to derive a sensitivity. The microprocessor performs subroutines to check jitter near map boundaries.

To start a squitter transmission, the clock circuits strobe the microprocessor. Since the shift register used to hold received data is also used to store the transmission data, a squitter transmission requires only a read from the ROM. When replying to an aircraft, the RBX stores the aircraft address in the RAM until the transmission formatting sequence starts.

The microprocessor also stores transmitted data when so requested by ATC. The microprocessor is also used to control performance monitor data storage.

The performance monitor drives interrupt lines to the microprocessor as well as encode data for requests from ATC. The microprocessor, when requested, will recall data from the RAM and the performance monitor to be sent to the Common ICAO Data Interchange Network (CIDIN) interface.

3.2.2 Transmitter

The transmitter consists of six modules packaged into a standard 19-inch rack. The modules, each of which is a removable plug-in unit, consist of an intermediate power amplifier (IPA) module, four 1,150-watt amplifier modules, and a four-to-one (4:1) combiner module. Inputs to each of the modules are through rear-mounted connectors. Figure 3-4 is a block diagram of the transmitter; Figure 3-5 shows the packaged transmitter rack.

We chose a modular approach in designing the transmitter to allow the RBX to remain operational at a reduced power capability if any one power amplifier module failed. This modular approach also enhances the maintainability of the RBX by allowing direct replacement of plug-in modules.

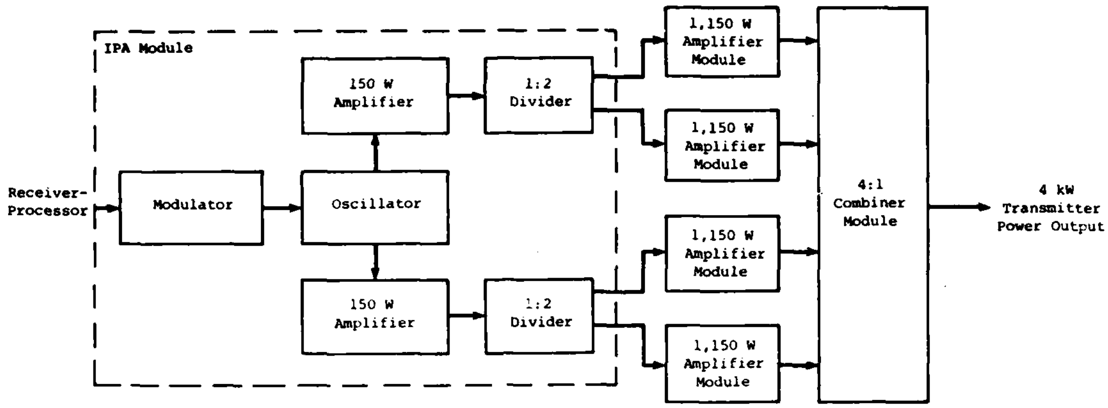


Figure 3-4. BLOCK DIAGRAM OF TRANSMITTER MODULES

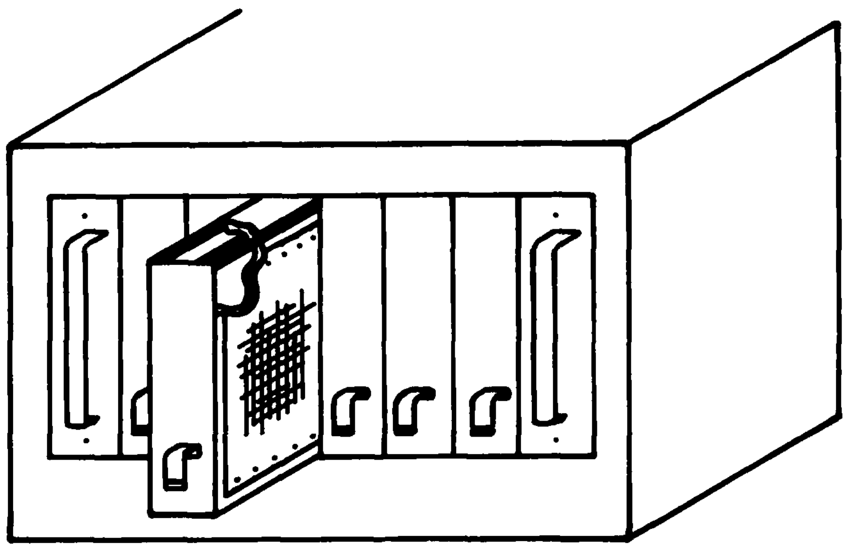


Figure 3-5. RBX TRANSMITTER MODULES

3.2.2.1 Intermediate Power Amplifier Module

The IPA module is a three-section casting packaged into a purchased RF shielded enclosure. The casting contains a modulator, oscillator, two 150-watt amplifiers, and two 1:2 power dividers. All subassemblies of the IPA use microstrip technology.

The output from each of the 150-watt amplifiers is divided via a 1:2 Wilkinson network that uses Balun coax with appropriate phasing to protect the amplifier transistors in case of a point failure.

3.2.2.2 1,150-Watt Amplifier Module

We used four 1,150-watt amplifier modules to obtain the required output of 4,000 watts. This modular approach allows reconfiguration to 1,000 or 2,000 watts output if desired, with redesigns of the IPA and combiner modules.

Each module consists of a manufactured two-section casting packaged into a purchased RF shielded enclosure. The amplifier itself operates from a minimum 63-watt input. The input is passed through a 1:3 power divider, which in turn feeds three amplifier subassemblies, each of which provides approximately 420 watts. Each 420-watt subassembly has four 110-watt power transistors driven by a single 100-watt transistor, using Wilkinson networks with quadrature phasing for power dividing and combining. In the case of a transistor failure, the quadrature phasing allows reflected power to be dissipated in an isolation resistor rather than an adjacent transistor. The power from the three subassemblies is combined through a 3:1 microstrip combiner and then passed through a circulator to provide essentially 1,150 watts of power at the module output.

Each 1,150-watt module contains its own power supply that utilizes large storage capacitors to provide essentially constant energy to the transistors during the pulse time.

3.2.2.3 4:1 Combiner Module

The 4:1 combiner module combines the inputs from the four 1,150-watt modules to provide a power output of approximately 4,000 watts.

A casting identical to that of the IPA module is used to achieve economies of scale, although only one section is needed for the combiner board. The stripline board uses a Wilkinson combiner made of Balun coax. The casting is packaged into a purchased enclosure.

3.2.3 Performance Monitor

The performance monitor module contains not only the performance monitor PCBs, but also the modem and CIDIN line interface required of an automated ATC facility. Both the required modem and line interface module were priced from commercially available sources.

The required performance monitoring, packaged in two PCBs, monitors the receiver test gate and noise test pulse from the clock as well as the video output -- all of which constitute the receiver gain test and receiver sensitivity test. The P1 transmit pulse, clock status flag, and remote thermistor are also monitored. The outputs of the performance monitor are buffered to the processor and passed to the local status indicator panels contained on the module front panel.

3.2.4 Power Supplies

The RBX requires 5-, 12-, and 48-volt power supplies. We used two rack-mounted power supply modules that were considered to be purchased as completely prepacked units containing all required front panels, meters, switches, handles, and connectors. The 48-volt power supply is contained in one module, and the 5- and 12-volt power supplies are contained in the second multiple-output module.

3.2.5 Cabinet

The cabinet housing the RBX modules is a commercially available cabinet containing a ventilating grill and blower assembly for cooling. The cabinet is approximately 68 inches high and 24 inches deep. The front width of 24 inches is sized to accept standard 19-inch racks and drawers. The cabinet assembly also includes various power strips, connectors, cables, and the wiring between modules, as well as the antenna connections and circulator.

3.2.6 Antenna

The antenna used with the RBX is a commercially available omnidirectional antenna for 1,015 to 1,040 MHz operation. It is vertically polarized with 8 dBi (referenced to isotropic) gain at 1,030 MHz. It may be mounted to a pipe 1 to 3 inches in diameter. The antenna is approximately 3 feet long and weighs 20 pounds.

CHAPTER FOUR

DEVELOPMENT OF RADAR BEACON TRANSPONDER COST

RBX equipment costs were developed on subassembly levels and combined to identify the expected cost of the transponder system. This chapter presents the results of the cost development. Information necessary to describe the equipment was developed by ARINC Research through detailed design of the RBX. This allowed development of a representative bill of materials for each subassembly. Parts chosen for the bill of materials were designed to meet the electronic equipment requirements of FAA specification FAA-G-2100/1.

4.1 DEVELOPMENT OF SUBASSEMBLY COSTS

The cost of each transponder module identified in Chapter Three was developed using traditional accounting methods. These methods require detailed parts identification for the production of modules, subassemblies, and systems. Each component was priced on the basis of OEM price lists for quantities necessary for production assemblies. A material handling charge of 25 percent was added to the cost of materials to allow for inventory control, pretesting, expected yield, and in-plant distribution. For major purchased items such as a power supply or antenna, a material handling charge of 13 percent was used in lieu of 25 percent, because less in-plant handling is required.

Calculations for assembly labor for each component were based on the nature of the component (e.g., two-lead devices, three-lead devices), using semiautomated insertion processes. The labor rate was derived from geographically corrected Department of Labor statistics for the electronic industry. A 1981 labor rate of $17.85 per hour was assumed to be typical for the expected manufacturers of this specialized electronics. Since the labor rate used is a semiloaded hourly wage, an overhead burden of 135 percent was applied to the labor costs. A subassembly inspection cost of 5 percent was added to the labor and burden. The addition of a 25 percent quality control and engineering cost to the sum of the material and labor costs provided the direct production cost of a module or the system. A 20 percent G&A cost and an expected 15 percent profit were included in determining the factory selling price of the unit. Since typical production practice is to manufacture equipment in subassemblies, the complete system must be assembled and tested before it is released for sale. To account for this activity and expense, an assembly and test cost was included in each cost analysis. The same markups and rates were used in determining the assembly and test cost, except that there are no material costs associated with the activity.

The following sections present the results of applying this cost estimating method to each module of the RBX presented in Chapter Three. Detailed parts lists associated with each configuration are included in the Appendixes.

4.2 RBX COST

4.2.1 Receiver-Processor

The receiver-processor module consists of an RF front end and seven PCBs containing the analog processor, decoder, timing assembly, and digital processor assembly. The entire receiver-processor is integrated into a chassis fitting a standard 19-inch rack. The chassis front panel contains the various required switches, lamps, and test points. Table 4-1 presents the cost development of the receiver-processor subassemblies based on material and labor estimates of each subassembly. Detailed parts list and labor data are presented in Appendix A. The assembly and test cost column of Table 4-1 reflects the cost of integrating the subassemblies into a working electronics unit and the cost associated with burn-in and final testing of the unit. The total expected selling price of the receiver-processor assembly is $7,813.

4.2.2 Transmitter

The transmitter module consists of six major modules -- the intermediate power amplifier, four 1,150-watt amplifiers, and a 4:1 combiner. The modules are designed to be independently inserted into a rack containing appropriate aligning pins and connectors. The rack itself is designed to fit into a standard 19-inch cabinet. Table 4-2 presents the cost development of the transmitter subassemblies. Detailed parts list and labor data are presented in Appendix B. The large cost associated with the frame in Table 4-2 is because six connectors are required at $150 each. The total expected selling price of the transmitter assembly is $29,640.

4.2.3 Performance Monitor

The performance monitor module includes the two performance monitor PCBs and the modem and line interface required for the CIDEN interface It is designed to fit into a chassis for installation in a standard 19-inch rack. The chassis front panel includes all necessary switches and lights. Table 4-3 presents the cost development of the performance monitor subassemblies. Detailed parts list and labor data are presented in Appendix C. The total expected selling price of the performance monitor assembly is $8,877.

Table 4-1. RBX RECEIVER-PROCESSOR COST DEVELOPMENT (1981 DOLLARS)

Cost Element	Module Cost								
	RF Front End	Analog Processor	Decoder	Timing PCB	Time-of-Day PCB*	Processor Assembly	Chassis	Assembly and Test	Total
Material Cost	428.91	335.79	163.17	98.30	177.00	489.94	265.81	--	1,958.92
Purchased Items (13% of Material Cost)	--	--	--	--	23.01	--	--	--	23.01
Material Handling (25% of Material Cost)	107.23	83.95	40.79	24.58	--	122.49	66.45	--	445.49
Labor ($17.85 per Hour)	182.96	51.50	55.62	75.06	3.57	138.73	233.25	111.12	851.81
Burden (135% of Labor)	247.00	69.53	75.09	101.33	4.82	187.29	314.88	150.01	1,149.95
Inspection (5% of Labor and Burden)	21.50	6.05	6.54	8.82	0.42	16.30	27.41	13.06	100.10
Subtotal	987.60	546.82	341.21	308.09	208.82	954.75	907.82	274.19	4,529.30
Engineering and Quality Control (25% of Subtotal)	246.90	136.71	85.30	77.02	52.21	238.69	226.95	68.55	1,132.33
Factory Cost	1,234.50	683.53	426.51	385.11	261.03	1,193.44	1,134.77	342.74	5,661.63
G&A (20% of Factory Cost)	246.90	136.71	85.30	77.02	52.21	238.69	226.95	68.55	1,132.33
Total Direct Cost	1,481.40	820.24	511.81	462.13	313.24	1,432.13	1,361.72	411.29	6,793.96
Profit (15% of Total Direct Cost)	222.21	123.04	76.77	69.32	46.99	214.82	204.26	61.69	1,019.10
Selling Price	1,703.61	943.28	588.58	531.45	360.23	1,646.95	1,565.98	472.98	7,813.06

*Purchased Item

Table 4-2. RBX TRANSMITTER COST DEVELOPMENT (1981 DOLLARS)

Cost Element	Module Cost								
	IPA Module	1.15 kW Module	1.15 kW Module	1.15 kW Module	1.15 kW Module	2:1 Combiner	Frame	Assembly and Test	Total
Material Cost	1,039.16	1,096.05	1,096.05	1,096.05	1,096.05	287.68	935.54	--	6,646.58
Purchased Items (13% of Material Cost)	--	--	--	--	--	--	--	--	--
Material Handling (25% of Material Cost)	259.79	274.01	274.01	274.01	274.01	71.92	233.89	--	1,661.14
Labor ($17.85 per Hour)	527.59	653.58	653.58	653.58	653.58	232.03	199.92	23.21	3,597.07
Burden (135% of Labor)	712.25	882.33	882.33	882.33	882.33	313.24	269.89	31.33	4,856.03
Inspection (5% of Labor and Burden)	61.99	76.80	76.80	76.80	76.80	27.26	23.49	1.16	421.10
Subtotal	2,600.78	2,982.77	2,982.77	2,982.77	2,982.77	932.13	1,662.73	55.70	17,182.42
Engineering and Quality Control (25% of Subtotal)	650.20	745.69	745.69	745.69	745.69	233.03	415.68	13.93	4,295.60
Factory Cost	3,250.98	3,728.46	3,728.46	3,728.46	3,728.46	1,165.16	2,078.41	69.63	21,478.02
G&A (20% of Factory Cost)	650.20	745.69	745.69	745.69	745.69	233.03	415.68	13.93	4,295.60
Total Direct Cost	3,901.18	4,474.15	4,474.15	4,474.15	4,474.15	1,398.19	2,494.09	83.56	25,773.62
Profit (15% of Total Direct Cost)	585.18	671.12	671.12	671.12	671.12	209.73	374.11	12.53	3,866.03
Selling Price	4,486.36	5,145.27	5,145.27	5,145.27	5,145.27	1,607.92	2,868.20	96.09	29,639.65

Table 4-3. RBX PERFORMANCE MONITOR COST DEVELOPMENT (1981 DOLLARS)					
Cost Element	Module Cost				
	Monitor	Modem	Chassis	Assembly and Test	Total
Material Cost	189.06	4,300.00	185.83	--	4,674.89
Purchased Items (13% of Material Cost)	--	559.00	--	--	559.00
Material Handling (25% of Material Cost)	47.27	--	46.46	--	93.73
Labor ($17.85 per Hour)	155.56	3.57	132.57	33.02	324.72
Burden (135% of Labor)	210.01	4.82	178.97	44.58	438.38
Inspection (5% of Labor and Burden)	18.28	0.42	6.63	3.88	29.21
Subtotal	620.18	4,867.81	550.46	81.48	6,119.93
Engineering and Quality Control (25% of Subtotal)	155.04	--	137.62	20.37	313.03
Factory Cost	775.22	4,867.81	688.08	101.85	6,432.96
G&A (20% of Factory Cost)	155.04	973.56	137.62	20.37	1,286.60
Total Direct Cost	930.26	5,841.37	825.70	122.22	7,719.55
Profit (15% of Total Direct Cost)	139.54	876.21	123.85	18.33	1,157.93
Selling Price	1,069.80	6,717.58	949.55	140.55	8,877.48

4.2.4 Power Supplies

The three required power supplies, considered to be purchased items, are completely packaged with all appropriate meters, switches, and connectors ready for installation in the 19-inch rack. The 48-volt power supply is in one chassis, and the 12-volt and 5-volt power supplies are packaged together in a second chassis as a multiple output power supply system. Table 4-4 presents the cost development of the power supplies. The labor costs represent the minimal effort required for installing the power supplies in the rack. No quality control or engineering costs are incurred, because they are reflected in the power supply package purchase price. The total expected selling price of the power supplies is $1,734.

4.2.5 Cabinet and Assembly and Test

The cabinet assembly is the actual cabinet into which the other subassemblies are mounted. The cost associated with the cabinet includes not only the cabinet, but the blowers, power strips, various connectors, the circulator between the antenna and the transmitter/receiver-processor, and all the labor time associated with the wiring between subassemblies.

The assembly and test time associated with the cabinet is the time needed to mount the subassemblies into the cabinet, make connections, and ensure that the RBX is in a state of operational readiness.

Table 4-5 presents the cost development of the cabinet and assembly and test of the cabinet. The cabinet has an associated cost of $3,498, while the assembly and test time adds an additional $186 to the cost, for a total cost of $3,684. Detailed parts list and labor data are presented in Appendix D.

4.2.6 Antenna

The required antenna for the RBX is considered to be a purchased item ready for installation. Table 4-6 presents the cost development of the antenna. The expected selling price of the antenna is $1,442.

4.2.7 Cost Summary

Table 4-7 shows the cost of the RBX with a 4 kW output. The costs shown are the per-unit production costs of the equipment, assuming production quantities of 100 to 200 units. System development costs and production tooling costs are not included. The factory selling price is the expected F.O.B. cost to the procuring activity.

Table 4-4. RBX SUPPLY COST DEVELOPMENT (1981 DOLLARS)

Cost Element	Module Cost		
	48-Volt Power Supply	12- and 5-Volt Power Supply	Total
Material Cost	565.00	535.00	1,100.00
Purchased Items (13% of Material Cost)	73.45	69.55	143.00
Material Handling (25% of Material Cost)	--	--	--
Labor ($17.85 per Hour)	2.68	2.68	5.36
Burden (135% of Labor)	3.62	3.62	7.24
Inspection (5% of Labor and Burden)	0.32	0.32	0.64
Subtotal	645.07	611.17	1,256.24
Engineering and Quality Control (25% of Subtotal)	--	--	--
Factory Cost	645.07	611.17	1,256.24
G&A (20% of Factory Cost)	129.01	122.23	251.24
Total Direct Cost	774.08	733.40	1,507.48
Profit (15% of Total Direct Cost)	116.11	110.01	226.12
Selling Price	890.19	843.41	1,733.60

Table 4-5. RBX CABINET AND ASSEMBLY AND TEST COST DEVELOPMENT (1981 DOLLARS)			
Cost Element	Module Cost		
	Chassis	Assembly and Test	Total
Material Cost	988.96	--	988.96
Purchased Items (13% of Material Cost)	--	--	--
Material Handling (25% of Material Cost)	247.24	--	247.24
Labor ($17.85 per Hour)	323.17	43.73	366.90
Burden (135% of Labor)	436.29	59.04	495.33
Inspection (5% of Labor and Burden)	32.31	5.14	37.45
Subtotal	2,027.97	107.91	2,135.88
Engineering and Quality Control (25% of Subtotal)	506.99	26.98	533.97
Factory Cost	2,534.96	134.89	2,669.85
G&A (20% of Factory Cost)	506.99	26.98	533.97
Total Direct Cost	3,041.95	161.87	3,203.82
Profit (15% of Total Direct Cost)	456.29	24.28	480.57
Selling Price	3,498.24	186.15	3,684.39

Table 4-6. RBX ANTENNA COST DEVELOPMENT (1981 DOLLARS)

Cost Element	Cost
Material Cost	925.00
Purchased Items (13% of Material Cost)	120.25
Material Handling (25% of Material Cost)	--
Labor ($17.85 per Hour)	--
Burden (135% of Labor)	--
Inspection (5% of Labor and Burden)	--
Subtotal	--
Engineering and Quality Control (25% of Subtotal)	--
Factory Cost	1,045.20
G&A (20% of Factory Cost)	209.05
Total Direct Cost	1,254.25
Profit (15% of Total Direct Cost)	188.14
Selling Price	1,442.39

Table 4-7. RBX TRANSPONDER COST (1981 DOLLARS)

Equipment	Cost
Receiver-Processor	7,813
Transmitter	29,640
Performance Monitor	8,877
Power Supplies	1,734
Cabinet	3,684
Antenna	1,442
Factory Selling Price	53,190

CHAPTER FIVE

DEVELOPMENT OF COSTS FOR VARIATIONS IN TRANSMITTER POWER

The cost analysis of prototype equipment or designs is often developed from engineering requirements or equipment that is still in various stages of evaluation. Evaluation criteria used must take these limitations into account and allow alternative scenarios to be evaluated for costs.

The RBX transmitter is currently specified to have a power output of 4 kW measured at the transmitter. However, the FAA requested a cost differential of transmitters with approximately 1 kW to 2 kW transmitter power outputs. Our modular transmitter design allowed us to determine such a cost without completely redesigning the transmitter. It must be emphasized, however, that if a 1 kW or 2 kW transmitter were being developed, a completely different design approach might have been chosen.

5.1 1 KW TRANSMITTER

Figure 5-1 is a diagram of the 4 kW transmitter. The possible cost of a 1 kW transmitter can be developed with the assumption that only one 1,150-watt amplifier module would be required. This would allow us to delete one 150-watt amplifier from the IIA, along with both 1:2 power divider networks. We could also eliminate the 4:1 power combiner and four connectors from the frame. The reduction of modules in the transmitter would also allow a reduction in assembly and test time. Table 5-1 shows the overall cost for our assumed 1 kW transmitter. The total cost of $9,582 is approximately 32 percent of the cost of the 4 kW transmitter design.

5.2 2 KW TRANSMITTER

A 2 kW transmitter may also be conveniently derived from Figure 5-1 by using only one 150-watt amplifier and two 1,150-watt amplifier modules, and replacing the 4:1 combiner with a 2:1 combiner. This would allow a reduction in both frame cost and assembly and test time. Table 5-2 shows the assumed cost for the 2 kW transmitter. The total cost of $17,531 is approximately 83 percent greater than the cost of a 1 kW transmitter, but 41 percent less than the cost of a 4 kW transmitter.

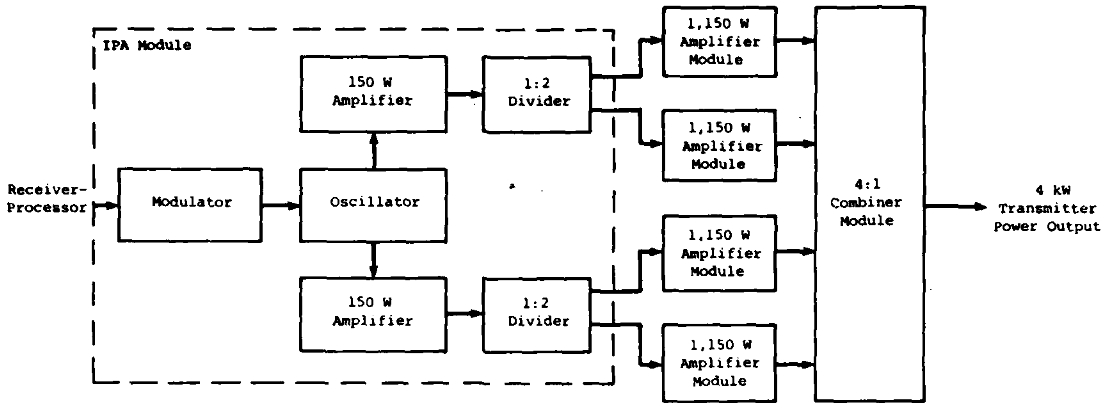


Figure 5-1. BLOCK DIAGRAM OF TRANSMITTER MODULES

5.3 RBX COST WITH VARIATIONS IN TRANSMITTER POWER

The total cost of the RBX with reduced transmitter power outputs would vary only with the cost of the transmitter; all other modules and subassemblies would remain the same. A reduced capacity 48-volt power supply could reduce the cost of the RBX by an additional $115. This option was not used in our analysis, however. Thus, an RBX with a 1 kW transmitter would cost approximately $33,130; the cost of an RBX with a 2 kW transmitter would be approximately $41,080.

Table 5-1. 1 KW RBX TRANSMITTER COST DEVELOPMENT (1981 DOLLARS)					
Cost Element	Module Cost				
	IPA Module	1.15 kW Module	Frame	Assembly and Test	Total
Material Cost	878.50	1,096.05	335.54	--	2,310.09
Purchased Items (13% of Material Cost)	--	--	--	--	--
Material Handling (25% of Material Cost)	219.63	274.01	83.85	--	577.49
Labor ($17.85 per Hour)	315.00	653.58	92.82	19.64	1,081.04
Burden (135% of Labor)	425.25	882.33	125.31	26.51	1,459.40
Inspection (5% of Labor and Burden)	37.02	76.80	10.91	2.31	127.04
Subtotal	1,875.40	2,982.77	648.43	48.46	5,555.06
Engineering and Quality Control (25% of Subtotal)	468.85	745.69	162.11	12.12	1,388.77
Factory Cost	2,344.25	3,728.46	810.54	60.58	6,943.83
G&A (20% of Factory Cost)	468.85	745.69	162.11	12.12	1,388.77
Total Direct Cost	2,813.10	4,474.15	972.65	72.70	8,332.60
Profit (15% of Total Direct Cost)	421.97	671.12	145.90	10.90	1,249.89
Selling Price	3,235.07	5,145.27	1,118.55	83.60	9,582.49

Table 5-2. 2 KW RBX TRANSMITTER COST DEVELOPMENT (1981 DOLLARS)

Cost Element	Module Cost						
	IPA Module	1.15 kW Module	1.15 kW Module	2:1 Combiner	Frame	Assembly and Test	Total
Material Cost	899.91	1,096.05	1,096.05	284.86	635.44	--	4,012.31
Purchased Items (13% of Material Cost)	--	--	--	--	--	--	--
Material Handling (25% of Material Cost)	224.98	274.01	274.01	71.22	158.86	--	1,003.08
Labor ($17.85 per Hour)	433.22	653.58	653.58	177.95	146.37	21.42	2,086.12
Burden (135% of Labor)	584.85	882.33	882.33	240.23	197.60	28.92	2,816.26
Inspection (5% of Labor and Burden)	50.90	76.80	76.80	20.91	17.20	2.52	245.13
Subtotal	2,193.86	2,982.77	2,982.77	795.17	1,155.47	52.86	10,162.90
Engineering and Quality Control (25% of Subtotal)	548.47	745.69	745.69	198.79	288.87	13.22	2,540.73
Factory Cost	2,742.33	3,728.46	3,728.46	993.96	1,444.34	66.08	12,703.63
G&A (20% of Factory Cost)	548.47	745.69	745.69	198.79	288.87	13.22	2,540.73
Total Direct Cost	3,290.80	4,474.15	4,474.15	1,192.75	1,733.21	79.30	15,244.36
Profit (15% fo Total Direct Cost)	493.62	671.12	671.12	178.91	259.98	11.90	2,286.65
Selling Price	3,784.42	5,145.27	5,145.27	1,371.66	1,993.19	91.20	17,531.01

CHAPTER SIX

RESULTS OF EVALUATION

This study has developed the unit production cost of an RBX on the basis of the accounting method of cost estimating. The RBX design data used for the cost analysis came from RBX circuit and equipment designs developed by ARINC Research Corporation. The production cost data were developed through detailed analysis of the methods of several leading electronics manufacturers producing both ground and airborne electronics equipment.

6.1 COST OF CONCEPT EVALUATED

Table 6-1 summarizes the unit production cost of the RBX developed by the accounting method. The values indicate the probable factory selling price per RBX. System development and production tooling costs are not included in the unit production cost. All costs are based on 1981 dollars without inflation.

Table 6-1. RBX TRANSPONDER COST (1981 DOLLARS)

Equipment	Cost
Receiver-Processor	7,813
Transmitter	29,640
Performance Monitor	8,877
Power Supplies	1,734
Cabinet	3,684
Antenna	1,442
Factory Selling Price	53,190

6.2 DEVELOPMENT OF COSTS FOR VARIATIONS IN TRANSMITTER POWER

The modular transmitter design allowed variations in the transmitter power outputs to be costed with slight redesigns of the transmitter IPA and/or the combiner module. Adaption of our modular transmitter design allowed us to postulate that a 1 kW transmitter would cost approximately $9,580, and a 2 kW transmitter would cost approximately $17,530. These transmitter costs may be compared with a 4 kW transmitter cost of $29,640.* It must be emphasized, however, that if our intent had been to develop a 1 kW or 2 kW transmitter, a completely different design approach might have been chosen.

*The cost of an RBX with a 1 kW transmitter would be approximately $33,130; an RBX with a 2 kW transmitter would cost approximately $41,080.

APPENDIX A

RECEIVER-PROCESSOR PARTS LISTS AND COST DEVELOPMENT DATA SHEETS

This appendix contains the work sheets used to develop costs of modules employed in the receiver-processor. These costs were the basis for the calculations presented in Chapter Four of the report.

SYSTEM RBX - RECEIVER - PROCESSOR

SHEET 1 OF 14

SUB-ASSEMBLY RF FRONT END

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MIXER	1	75.00	75.00		50			
PRESELECTOR	1	84.00	84.00		50			
COUPLER	1	80.00	80.00		50			
CASTING	1	32.00	32.00		100			
COVER	1	2.50	2.50		15			
CABLE (6in.)	5	1.10	5.50		125			
CONNECTOR (SMA)	10	2.65	26.50		900			
MISC. HDW.	LOT	1.00	1.00		50			
LIMITER	1	36.05	36.05	2454	348			
LOCAL OSCILLATOR	1	32.60	32.60	2454	711			
LOW NOISE AMP	1	53.76	53.76	2454	489			
TOTALS			428.91	7362	2888			

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SYSTEM RF FRONT END

SHEET 2 OF 14

SUB-ASSEMBLY LIMITER

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
FET	1	.75	.75		6			
SM2	2	5.30	10.60		16			
PLS2	1	19.00	19.00		8			
RESISTOR	2	.03	.06		10			
CAPACITOR	4	.13	.52		20			
COIL	1	.12	.12		6			
SUBSTRATE	1	5.00	5.00	2454	50			
TOTALS			36.05	2454	116 x 3 348			

SYSTEM RF FRONT END

SUB-ASSEMBLY LOCAL OSCILLATOR

SHEET 3 OF 14

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
DG125	1	13.25	13.25		8			
1N4154	1	7.29	7.29		5			
2N3546	2	1.95	3.90		12			
RESISTOR	9	.03	.27		45			
CAPACITOR	11	.13	1.43		55			
CAPACITORY-VAR	2	.23	.46		20			
COIL	6	.12	.72		36			
FILTER	1	.28	.28		6			
SUBSTRATE	1	5.00	5.00	2454	50			
TOTALS			32.60	2454	237 x 3 711			

SYSTEM RF FRONT END

SUB-ASSEMBLY LOW NOISE AMPLIFIER

SHEET 4 OF 14

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
LT 4700	2	18.00	36.00		20			
RESISTOR	9	.77	6.93		45			
CAPACITOR	7	.80	5.60		42			
COIL	1	.23	.23		6			
SUBSTRATE	1	5.00	5.00	2454	50			
TOTALS			53.76	2454	163 x 3 489			

SYSTEM RBX - RECEIVER-PROCESSOR

SUB-ASSEMBLY ANALOG PROCESSOR

SHEET 5 OF 14

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
µA715	1	5.50	5.50		8			
MPS6515	1	.32	.32		8			
SL 1521	8	29.35	234.80		64			
IN4153	1	.30	.30		5			
IN5711	5	1.43	7.15		25			
2N2222A	1	.40	.40		6			
2N5086	2	.21	.42		12			
RESISTOR	35	.03	1.05		175			
RESISTOR (1K)	10	.71	7.10		50			
CAPACITOR	23	.13	2.99		115			
CAPACITOR VAR	1	1.14	1.14		5			
COIL	1	.12	.12		6			
PC.BOARD	1	12.00	12.00	818	50			
MISC. HDW.	LOT	.50	.50		25			
CONNECTOR	1	2.00	2.00		30			
PASS.RD.FILTER	1	60.00	60.00		25			
DC.TEST	-	-	-		80			
TOTALS			335.79		689 x 3 2067			

SYSTEM RECEIVER-PROCESSOR

SHEET 6 OF 14

SUB-ASSEMBLY DECODER

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
µ760	1	3.28	3.28		10			
UA710T	1	.59	.59		10			
DM75529	2	1.29	2.58		24			
MC14528AL	1	3.21	3.21		10			
IN 277	1	.21	.21		5			
IN 3666	2	1.19	2.38		10			
IN 4009	5	.10	.50		25			
2N3646	3	.20	.60		18			
2N4401	1	.40	.40		6			
2N5086	1	.17	.17		6			
5404	2	.74	1.48		16			
5408	2	.74	1.48		16			
5414	1	1.80	1.80		8			
5432	1	1.15	1.15		8			
5478	1	1.30	1.30		8			
54121	1	1.50	1.50		8			
54161	1	2.50	2.50		10			
54163	4	2.50	10.00		40			
54164	4	1.85	7.40		32			
54LS21	2	.60	1.20		16			
RESISTOR	24	.03	.72		120			
RESISTOR-VAR	1	.42	.42		15			
TOTALS								

SYSTEM RBX - RECEIVER

SHEET 7 OF 14

SUB-ASSEMBLY DECODER

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CAPACITOR	16	.13	2.08		80			
COIL	6	.12	.72		30			
FILTER(SAW)	1	100.00	100.00		25			
PC BOARD	1	12.00	12.00	818	50			
MISC. HDW.	LOT	1.50	1.50		50			
CONNECTOR	1	2.00	2.00		30			
TESTING	-	-	-		80			
TOTALS			163.17	818	766 x 3 2298			

SYSTEM RECEIVER-PROCESSOR

SHEET 8 OF 14

SUB-ASSEMBLY TIMING PCB

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
5400	1	.70	.70		8			
5404	3	.74	2.22		24			
5408	3	.74	2.22		24			
5478	2	1.30	2.60		16			
54121	3	1.50	4.50		24			
54161	1	2.50	2.50		10			
54163	8	2.50	20.00		80			
54S271	1	2.15	2.15		11			
54LS21	3	0.60	1.80		24			
IN751A	1	0.20	0.20		5			
2N546	1	0.58	0.58		6			
2N3812	1	13.85	13.85		12			
DM75S29	2	1.29	2.58		24			
8T10	2	1.75	3.50		20			
SE555	1	2.40	2.40		10			
NE556	2	3.73	7.46		20			
CAPACITOR	23	0.13	2.99		138			
RESISTOR	32	0.03	0.96		160			
COIL	3	0.23	0.69		18			
CRYSTAL	1	7.00	7.00		35			
SWITCH	1	2.40	2.40		100			
PC BOARD	1	12.00	12.00	818	50			
TOTALS								

SYSTEM RBX

SUB-ASSEMBLY TIMING CIRCUIT

SHEET 9 OF 14

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CONNECTOR	1	2.00	2.00		30			
HARDWARE	LOT	1.00	1.00		100			
DC TESTING	-	-	-		180			
TOTALS			98.30	818	1129 x 3 (3387)			

SYSTEM RECEIVER-PROCESSOR

SHEET 10 OF 14

SUB-ASSEMBLY PROCESSOR ASSEMBLY-PCB No.1

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2708	2	10.14	20.28		10			
5416	4	1.55	6.20		32			
5417	2	1.55	3.10		16			
5421	4	.85	3.40		32			
5473	6	1.80	10.80		48			
5485	7	3.50	24.50		70			
54LS257	1	3.32	3.32		10			
8085	1	17.85	17.85		20			
8205	2	4.85	9.70		16			
8212	19	4.90	93.10		190			
8257-5	1	16.45	16.45		20			
8355-2	1	7.80	7.80		20			
2114AL-1	1	.40	.40		20			
2N2222A	20	.40	8.00		120			
CRYSTAL (4MHZ)	1	60.00	60.00		35			
RESISTOR	30	.03	.90		150			
CAPACITOR	15	.13	1.95		75			
CONNECTOR (40P)	1	2.00	2.00		30			
PC BOARD	1	12.00	12.00	818	50			
TESTING	-	-	-		75			
TOTALS			301.75	818	1039 x 3 3117			

SYSTEM RECEIVER-PROCESSOR

SHEET 11 OF 14

SUB-ASSEMBLY PROCESSOR ASSEMBLY-PCB No.2

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
5402	1	0.70	0.70		8			
5404	1	0.74	0.74		8			
5407	1	0.65	0.65		8			
5408	4	0.74	2.96		32			
5432	1	1.15	1.15		8			
5478	1	1.30	1.30		8			
5486	1	0.92	0.92		8			
5491A	3	1.54	4.62		24			
54153	8	2.20	17.60		80			
54157	4	2.20	8.80		40			
54166	3	1.80	5.40		30			
54198	11	4.40	48.40		132			
MC8504P	6	8.60	51.60		48			
CONNECTOR	1	2.00	2.00		30			
PC BOARD	1	12.00	12.00	818	50			
TESTING	-	-	-		30			
TOTALS			158.84	818	514 x 3 1632			

SYSTEM RECEIVER-PROCESSOR

SUB-ASSEMBLY PROCESSOR ASSEMBLY-PCB No. 3

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
5404	1	.74	.74		8			
5408	2	.74	1.48		16			
5432	1	1.15	1.15		8			
5478	1	1.30	1.30		8			
54161	3	2.50	7.50		8			
54LS21	1	.60	.60		8			
DM75S29	2	1.29	2.58		24			
PC BOARD	1	12.00	12.00	818	50			
CONNECTOR	1	2.00	2.00		30			
TESTING	-	-	-		30			
TOTALS			29.35	818	190 x 3 570			

SYSTEM RECEIVER PROCESSOR

SUB-ASSEMBLY CHASSIS

SHEET 13 OF 14

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CHASSIS	1	95.65	95.65		44			
STRUTS	7	2.75	19.25		60			
NUT STRIP	7	1.93	13.51		10			
HANDLES	2	2.08	4.16		10			
PC.BD.CON.	7	1.26	8.82		240			
FRONT PANEL	1	8.00	8.00		22			
TOP COVER	1	6.50	6.50		22			
PUSH.BT.SWITCH	1	.50	.50		25			
TOGGLE SW.	3	1.20	3.60		75			
LAMP	1	.62	.62		15			
TEST PT.	2	.50	1.00		30			
FRT.PAN.PC BD	1	10.00	10.00	818	50			
CABLING	LOT	5.00	5.00		2000			
MISC. HDW.	LOT	4.00	4.00		100			
DIVIDER	2	20.00	40.00		50			
TYPE N CONNECTOR	2	5.27	10.54		25			
BNC CONNECTOR	1	0.78	0.78		25			
MS CONNECTOR	2	16.99	33.88		1280			
TOTALS			265.81	818	4083 x 3 (12249)			

SYSTEM RECEIVER - PROCESSOR

SUB-ASSEMBLY ASSEMBLY & TEST

SHEET 14 OF 14

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
RF Front End	1				50			
Analog Process	1				25			
Decoder	1				25			
Timing PCB	1				25			
Processor Assbly	1				75			
Time of Day PCB	1				25			
Burn In					1000			
Test					5000			
TOTALS					6225			

APPENDIX B

TRANSMITTER PARTS LISTS AND COST DEVELOPMENT DATA SHEETS

This appendix contains the work sheets used to develop costs of modules employed in the transmitter. These costs were the basis for the calculations presented in Chapter Four of the report.

SYSTEM RBX - TRANSMITTER

SHEET 1 OF 18

SUB-ASSEMBLY Intermediate Power Amplifier (IPA) Module

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MODULATOR	1	447.93	447.93	2454	1344			
OSCILLATOR	1	49.28	49.28	2454	948			
150W AMP	2	117.84	235.68	4908	2136			
1:2 DIVIDER	2	21.41	42.82	4908	3330			
CHASSIS	1	263.45	263.45	-	5775			
ASSEMBLY & TEST	-	-	-	-	1300			
TOTALS			1039.16	14724	14833			

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SYSTEM IPA MODULE

SUB-ASSEMBLY Modulator

SHEET 2 OF 18

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
5404	1	.74	.74		8			
5478	2	1.30	2.60		16			
54121	4	1.50	6.00		32			
IN 914	4	.12	.48		20			
2N 918	2	2.10	4.20		10			
RCA 3019	1	.78	.78		25			
HP33144A	2	207.00	414.00		30			
RESISTOR	24	.03	.72		120			
RESIST. VAR	2	.42	.84		30			
CAPAC. DISC	17	.13	2.21		85			
COIL	3	.12	.36		12			
CRYSTAL	1	7.00	7.00		35			
SUBSTRATE	1	8.00	8.00	2454	25			
TOTALS			447.93	2454	448 x 3 1344			

SYSTEM IPA MODULE

SHEET 3 OF 18

SUB-ASSEMBLY Oscillator

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
2N5861	1	1.20	1.20		6			
SD1522	2	13.10	26.20		100			
MPN 13401	1	.88	.88		15			
RESISTOR	7	.03	.21		35			
CAPACITOR	13	.13	1.69		65			
CAPACITOR FT	3	.23	.69		15			
CAPACITOR TN	1	.41	.41		5			
TUNING TUBE	1	10.00	10.00		50			
SUBSTRATE	1	8.00	8.00	2454	25			
TOTALS			49.28	2454	316 x 3 948			

SYSTEM IPA MODULE

SUB-ASSEMBLY 150 Watt Amplifier

SHEET 4 OF 18

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
SD 1526	1	14.80	14.80		50			
SD 1536	1	28.00	28.00		50			
SD 1538	1	34.60	34.60		50			
MA 47021	1	18.40	18.40		6			
RESISTOR	6	.03	.18		30			
CAPACITOR	16	.13	2.08		80			
COIL	6	.42	2.52		30			
TNCAPS	2	4.63	9.26		10			
SUBSTRATE	1	8.00	8.00	2454	50			
TOTALS			117.84	2454	356 x 3 1068			

SYSTEM IPA MODULE

SHEET 5 OF 18

SUB-ASSEMBLY 1:2 DIVIDER

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
BALUN	2	.32	.64		500			
RESISTOR	1	.77	.77		5			
SUBSTRATE	1	20.00	20.00	2454	50			
TOTALS			21.41	2454	555 x 3 (1665)			

SYSTEM IPA MODULE

SHEET 6 OF 18

SUB-ASSEMBLY Casting & Enclosure (Chassis)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CASTING	1	78.00	78.00		100			
ENCLOSURE	1	24.95	24.95		150			
FRONT PANEL	1	2.50	2.50		100			
HANDLE	1	3.00	3.00		25			
CONNECTOR	1	150.00	150.00		1500			
MISC. HDW.	LOT	5.00	5.00		50			
TOTALS			263.45		1925 x 3 5775			

SYSTEM IPA MODULE

SUB-ASSEMBLY ASS'Y & TEST

SHEET 7 OF 18

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
OSCILLATOR	1				50			
MODULATOR	1				50			
150W. AMP	2				100			
1:2 DIVIDER	2				100			
FUNCT. TEST					500			
BURN-IN					500			
TOTALS					1300			

SYSTEM RBX TRANSMITTER

SUB-ASSEMBLY 1150 WATT AMPLIFIER MODULE

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
420 W amp. Mod.	3	212.51	637.53	7362	12105			
1:3 Divider	1	49.71	49.71	2454	3660			
3:1 Combiner	1	49.71	49.71	2454	3660			
Power Supply	1	17.65	17.65	818	702			
Chassis	1	271.45	271.45		2050			
Assembly & Test	1	-	-		1350			
Circulator	1	70.70	70.70		-			
TOTALS			1096.05	13088	23527			

SYSTEM 1150 WATT AMPLIFIER MODULE

SUB-ASSEMBLY 420 WATT AMPLIFIER MODULE

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
SD1536	1	28.00	28.00		50			
SD1538	4	34.60	138.40		200			
RESISTOR TF	6	.77	4.62		30			
RESITOR W.WD	2	1.05	2.10		40			
BALUN	2	.32	.64		500			
CONNECTOR SMA	5	2.65	13.25		450			
SUBSTRATE	1	25.00	25.00	2454	50			
MISC. HDW.	LOT	.50	.50		25			
TOTALS			212.51	2454	1345 x 3 4035			

SYSTEM 1150 WATT AMPLIFIER MODULE

SHEET 10 OF 18

SUB-ASSEMBLY 3:1 DIVIDER / COMBINER

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
BALUN	3	.32	.96		750			
RESIST. W.WD.	3	1.05	3.15		60			
CONNECTOR	4	2.65	10.60		360			
SUBSTRATE	1	35.00	35.00	2454	50			
TOTALS			49.71	2454	1220 x 3 3600			

SYSTEM 1150 WATT AMPLIFIER

SHEET 11 OF 18

SUB-ASSEMBLY POWER SUPPLY

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MJE 1100	1	1.53	1.53		8			
1N4751	1	.45	.45		5			
TRANSIST. SI	1	.15	.15		6			
RESISTOR	4	.03	.12		20			
CAP	3	1.69	5.07		30			
CAP DISC	3	.13	.39		15			
COIL	2	.12	.24		10			
PC. BOARD	1	7.00	7.00	818	50			
CONNECTOR	1	2.65	2.65		90			
TOTALS			17.65	818	234 x 3 702			

SYSTEM 1150 WATT AMPLIFIER MODULE

SUB-ASSEMBLY CASTING & ENCLOSURE (CHASSIS)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CASTING	1	78.00	78.00		100			
COVER	1	5.00	5.00		25			
ENCLOSURE	1	24.95	24.95		150			
FRONT PANEL	1	2.50	2.50		100			
HANDLE	1	3.00	3.00		25			
CONNECTOR	1	150.00	150.00		1500			
MISC. HDW.	LOT	8.00	8.00		150			
TOTALS			271.45		2050			

SYSTEM 1150 WATT AMPLIFIER MODULE

SUB-ASSEMBLY ASSEMBLY & TEST

SHEET 13 OF 18

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
POWER SUPPLY	1				50			
1:3 DIVIDER	1				50			
3:1 COMBINER	1				50			
420 W AMP. MOD.	1				150			
CIRCULATOR	1				50			
BURN-IN					500			
FUNCT TEST					500			
TOTALS					1350			

SYSTEM RBX TRANSMITTER

SUB-ASSEMBLY 4:1 COMBINER MODULE

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
COMBINER	1	24.23	24.23	2454	4695			
CHASSIS	1	263.45	263.45		5775			
ASSEMBLY & TEST	-	-	-		75			
TOTALS			287.68	2454	10545			

SYSTEM 4:1 COMBINER MODULE

SUB-ASSEMBLY COMBINER NETWORK

SHEET 15 OF 18

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL.RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
BALUN	6	.32	1.92		1500			
RESISTOR TF	3	.77	2.31		15			
SUBSTRATE	1	20.00	20.00	2454	50			
TOTALS			24.23	2454	1565 x 3 4695			

SYSTEM 4:1 COMBINER MODULE

SUB-ASSEMBLY CASTING & ENCLOSURE (CHASSIS)

SHEET 16 OF 18

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CASTING	1	78.00	78.00		100			
ENCLOSURE	1	24.95	24.95		150			
FRONT PANEL	1	2.50	2.50		100			
HANDLE	1	3.00	3.00		25			
CONNECTOR	1	150.00	150.00		1500			
MISC. HDW.	LOT	5.00	5.00		50			
TOTALS			263.45		1925 x 3 5775			

SYSTEM RBX TRANSMITTER

SUB-ASSEMBLY FRAME

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
FRAME	1	27.54	27.54		150			
CONNECTOR	6	150.00	900.00		9000			
HANDLE	2	3.00	3.00		50			
CABLING	LOT	5.00	5.00		2000			
TOTALS			935.54		11200			

SYSTEM RBX - TRANSMITTER

SUB-ASSEMBLY ASS'Y & TEST

SHEET 18 OF 18

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
IPA MODULE	1				50			
1.15KW MODULE	4				200			
4:1 COMBINER	1				50			
FUNCT. TEST					500			
BURN IN					500			
TOTALS					1300			

APPENDIX C

PERFORMANCE MONITOR/MODEM PARTS LISTS AND COST DEVELOPMENT DATA SHEETS

This appendix contains the work sheets used to develop costs of modules employed in the performance monitor/modem. These costs were the basis for the calculations presented in Chapter Four of the report.

SYSTEM PERFORMANCE MONITOR

SHEET 1 OF 6

SUB-ASSEMBLY PCB No. 1

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
5400	3	0.70	2.10		24			
5404	1	0.74	0.74		8			
5408	2	0.74	1.28		16			
54121	1	1.50	1.50		8			
54163	2	2.50	5.00		16			
54195	1	1.30	1.30		8			
54S271	1	2.15	2.15		8			
54LS32	1	0.74	0.74		8			
IN914	1	0.12	0.12		5			
IN4154	1	0.13	0.13		5			
IN705A7	1	2.10	2.10		5			
2N915	6	0.43	2.58		36			
2N4360	2	0.32	0.64		12			
LM741	2	0.27	0.54		16			
SE527	7	0.52	3.64		56			
NE556	2	3.75	7.50		16			
LH0032	1	24.50	24.50		8			
8T10	5	1.75	8.75		40			
RESISTOR	50	0.03	1.50		250			
VAR RESISTOR	9	0.42	3.78		90			
CAPACITOR	4	0.13	0.52		20			
SUBSTRATE	1	48.00	48.00	2454	50			
TOTALS	(contd)							

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SYSTEM PERFORMANCE MONITOR

SHEET 2 OF 6

SUB-ASSEMBLY PCB No. 1 (contd.)

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CONNECTOR	1	2.00	2.00		30			
TESTING	-	-	-		25			
TOTALS			121.11	2454	760 x 3 2280			

SYSTEM PERFORMANCE MONITOR

SHEET 3 OF 6

SUB-ASSEMBLY PCB No. 2

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
5432	1	1.15	1.15		8			
IN914	17	0.12	2.04		85			
IN4148	2	0.13	0.26		10			
2N915	8	0.43	3.44		48			
2N2222A	1	0.40	0.40		6			
SE527	1	0.52	0.52		8			
CAPS	3	0.13	0.39		15			
RESISTORS	21	0.03	0.63		105			
VAR. RESIST	1	0.42	0.42		10			
5200F1	6	0.90	5.40		48			
5200F5	1	0.90	0.90		8			
5200F7	1	0.90	0.90		8			
SUBSTRATE	1	48.00	48.00	2454	50			
CONNECTOR	1	2.00	2.00		30			
MISC HARDWARE	LOT	1.50	1.50		45			
TESTING					25			
TOTALS			67.95	2454	509 x 3 1527			

SYSTEM RBX - MODEM

SUB-ASSEMBLY

SHEET 4 OF 6

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MODEM CODEX LSI 48/V.27 ,	1	3500.00	3500.00		150			
LINE INTERFACE, DU11	1	800.00	800.00		50			
TOTALS			4300.00		200			

SYSTEM RBX - MONITOR-MODEM

SHEET 5 OF 6

SUB-ASSEMBLY CHASSIS

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
CHASSIS	1	95.65	95.65		44			
STRUTS	3	2.75	8.25		60			
NUT STRIP	3	1.93	5.79		15			
HANDLES	2	2.08	4.16		15			
PC. BD. CONN.	3	1.26	3.78		90			
FRONT PANEL	1	8.00	8.00		22			
TOP COVER	1	6.50	6.50		22			
PUSH BT. SW.	1	.50	.50		25			
TOGGLE SW.	3	1.20	3.60		75			
LAMP	1	.62	.62		15			
TEST POINTS	6	.50	3.00		90			
FR. PANEL PC. BD	1	1.00	1.00	6.8	50			
CABLING	LOT	5.00	5.00		100			
MISC. HDW.	LOT	4.00	4.00		100			
MS CONNECT.	2	16.99	33.98		1280			
WIRING	LOT	2.00	2.00		200			
TOTALS			185.83	818	2203 x 3 6609			

SYSTEM NBX - MONITOR-MODEM

SUB-ASSEMBLY ASS'Y & TEST

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
MONITOR	1				50			
MODEM	1				50			
CHASSIS	1				250			
TEST					1000			
BURN IN					500			
TOTALS					1850			

APPENDIX D

CHASSIS PARTS LISTS AND COST DEVELOPMENT DATA SHEETS

This appendix contains the work sheets used to develop costs of modules employed in the chassis. These costs were the basis for the calculations presented in Chapter Four of the report.

SYSTEM RBX - CHASSIS

SUB-ASSEMBLY

SHEET 1 OF 2

ITEM NAME OR CATEGORY	QTY	UNIT COST	TOTAL COST	LABOR HOURS PER 1000 UNITS		UNIT FAILURE RATE	TOTAL FAILURE RATE	QTY x FAIL. RATE x UNIT COST
				MANUFACTURING	ASSEMBLY			
VERT. CABINET	1	263.00	263.00		-			
BLOWER ASSY.	1	137.00	137.00		-			
VENT GRILL	1	19.00	19.00		-			
SLIDES	2PR.	15.00	15.00		1000			
CABLE TROUGH	1	21.00	21.00		-			
CABLE RETRACT.	2	16.00	32.00		-			
POWER STRIP	1	33.00	33.00		-			
DIVIDER PANEL	4	11.00	44.00		-			
CIRCULATOR	1	270.00	270.00		200			
ANTENN CONN.	1	55.00	55.00		100			
WECO BLOCK	1	3.50	3.50		25			
2-WAY RECEPT.	1	7.50	7.50		100			
3SJ12 CABLE	20 FT.	.30/ft	6.00		50			
MS CONNECTOR	4	16.99	67.96		2560			
WIRING	-	-	-		2000			
TOTALS			988.96		6035 x 3 18105			

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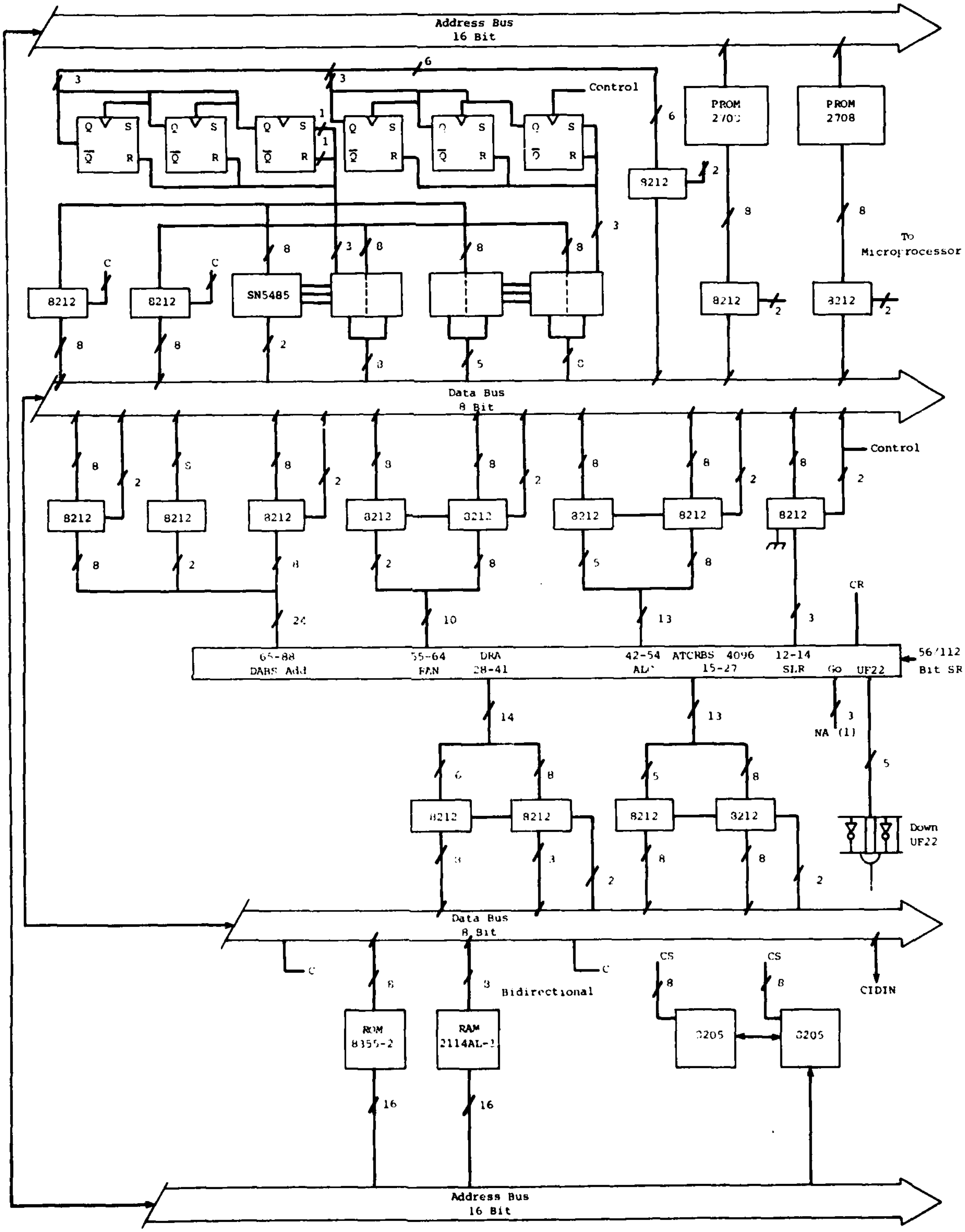
APPENDIX E

MICROPROCESSOR SYSTEM INTERFACE SCHEMATIC



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